JOYSTICK-OPERATED DRIVING SYSTEM

Background of the Invention

The present invention relates to a system for controlling a motor vehicle, and particularly for operating the vehicle accelerator and brakes. This invention can be readily applied to vehicle control systems for physically impaired drivers.

A conventional motor vehicle, such as an automobile, is designed for a driver having full and substantially unrestricted use of all of their limbs. The standard vehicle controls include a rotary operating steering wheel, a depressible brake pedal, and a depressible accelerator pedal. Of course, it is known that the steering wheel is operated manually, while the brake and accelerator pedals are operated by the driver's feet. Current production vehicles assume that the driver has full use of his/her hands and feet in order to operate these vehicle controls.

Unfortunately, a significant percentage of the driving population does not have full use of all of their limbs. For instance, drivers with certain physical disabilities may be unable to use their legs to operate the brake and accelerator pedals. Although no production vehicles have been developed to account for physically-impaired drivers, a significant amount of effort has been expended in developing systems that can be integrated into an existing vehicle control system to accommodate this driving population. One such system is depicted and described in U.S Patent No. 4,722,416, which issued on February 2, 1998 to one of the inventors of the present invention. A system embodying the teachings of the '416 patent has been sold by Ahnafield Corporation as its "Joystick Driving Control®" system. The basic components of this

system are shown in Fig. **1**. In particular, a vehicle **V**, which includes a steering wheel **S**, a brake pedal **B**, and an accelerator pedal **A**, is provided with a braking/acceleration control system **10** that integrates with the vehicle controls. A joystick controller **12** is provided that can be manually manipulated by the physically-impaired driver. This joystick controller is linked to a control box **14** which carries an electronic circuit or microprocessor that produces control signals in response to movement of the joystick controller **12**. These signals operate a brake control cylinder **16** or an accelerator control cylinder **18**. These cylinders are part of a hydraulic system that can be actuated by signals from the control box **14** to depress or retract either of the two control pedals **B**, **A**. In certain applications, the joystick controller **12** can be a two-axis joystick, meaning that movement in one direction, say left or right, can be used to operate the vehicle steering in lieu of the steering wheel **S**, while movement in a perpendicular direction, such as forward and backwards, controls either the brake or accelerator pedal.

While the Joystick Driving Control® vehicle control system has been very successful in improving the freedom and mobility of the physically-impaired driver, there is always room for improvement. One problem faced by this and other vehicle control systems is that they require significant modification of the existing vehicle and are very difficult and time-consuming to install. Another difficulty faced by some driving control systems is the "fail-safe" mode of operation of the system. For instance, in some prior vehicle control systems, a failure of certain components of the system can compromise the ability of the driver to achieve a safe, controlled stop of the vehicle. The Joystick Driving Control® system of the Ahnafield Corporation has implemented a fail-safe condition in which all actuators return to a neutral position so that there can be no

inadvertent application of the accelerator. In addition, this system provides redundancy for the brake actuators so that the failure of one actuator does not leave the brake pedals inoperable. While the Joystick Driving Control® system has an impeccable safety record, there again is always room for improvement to insure the continued safety of the physically-impaired driver. Thus, there remains a need for improvements to vehicle control systems, particularly those intended for use by the physically-impaired driver.

SUMMARY OF THE INVENTION

To address this continuing need, the present invention provides a system for use by a physically impaired driver for controlling the brake pedal and accelerator pedal of a vehicle. In one embodiment, the system includes a manually manipulated hand controller, movable in a first direction to control the brake pedal and in a second direction to control the accelerator pedal. An actuator assembly includes a first actuator operably coupled to the brake pedal to depress the brake pedal when activated, and a second actuator operably coupled to the accelerator pedal to depress the accelerator pedal when activated. An electrical control system connects the hand controller to the actuator assembly and is operable to activate the first actuator when the hand controller is moved in the first direction and to activate the second actuator when the hand controller is moved in the second direction. In one feature of this embodiment, a housing is provided for supporting the actuator assembly, in which the housing is pivotably mounted to the vehicle above the brake pedal so that the actuator assembly pivots relative to the vehicle when the first actuator is activated to depress the brake pedal. The accelerator actuator is provided with a U-joint linkage to accommodate this pivoting movement of the actuator assembly.

The housing can include a mounting clamp configured to engage the steering column of the vehicle. This clamp can be affixed with only minimal modification to the vehicle dashboard. The housing also includes a hinge connecting the housing to the mounting clamp to accommodate the pivoting movement of the housing and actuator assembly when the first actuator operates on the vehicle brake pedal. In one feature of the invention, a support arm is provided for connecting the hand controller to the housing. The support arm holds the hand controller in a position that does not interfere with the wheelchair of a driver while orienting the hand controller for easy access by the driver. In one embodiment, a support arm extends from the mounting clamp for supporting the hand controller. Preferably, the housing includes exterior padding for the comfort of the driver.

In another feature of the invention, the actuator assembly includes a brake actuator system operably coupled to the brake pedal to depress the brake pedal when

activated. The brake actuator system includes a primary electric motor and a secondary electric motor, operable independent of the primary electric motor. The secondary motor is preferably operable in the event of an emergency or the occurrence of a failure of the primary motor. A linkage assembly is provided for commonly coupling the primary and secondary electric motors to the brake pedal. In a preferred embodiment, each of the primary and secondary motors includes a rack and pinion arrangement for translating motor rotary motion to linear motion. A link extends from each rack to a common bracket engaged to the vehicle brake pedal or pedal arm.

In accordance with a further aspect of the invention, at least the primary brake motor is a reversible motor. The actuator assembly includes motor control circuitry that is operable in response to signals from the hand controller to activate the primary brake motor in a forward direction to depress the vehicle brake pedal. The motor control circuitry is also operable to direct the primary brake motor to operate in a reverse direction to release the brake pedal. The secondary brake motor can be similar controlled. In some embodiments, the secondary brake motor is operable in emergency braking conditions. In these embodiments, the secondary motor is capable of more rapid actuation of the brake pedal than the primary brake motor. In contrast, the primary brake motor is configured for more accurate actuation to permit partial activation of the brake, as may occur during normal driving conditions.

The actuator assembly also includes an accelerator actuator system that is operably coupled to the accelerator pedal to depress the accelerator pedal when activated. The electrical control system is also operable to activate the accelerator actuator when the hand controller is moved in the second direction. The accelerator actuator includes an electric motor that is connected to a rack gear through a free-wheeling clutch. When the clutch is energized, the accelerator motor extends the rack gear and associated linkage to depress the accelerator pedal. When the accelerator is to be deactivated, the clutch is deactivated – i.e., is permitted to freewheel – so that the return spring of the accelerator pedal itself pushes the accelerator linkage back to its neutral position.

In an embodiment of the invention, the actuator assembly includes a support plate that commonly supports the accelerator motor as well as the primary and secondary

braking motors. The support plate is pivotably mounted to the vehicle above the brake pedal so that the support plate pivots relative to the vehicle when the brake actuator system is activated to depress the brake pedal.

In another aspect of the invention, the manually manipulated hand controller includes a joystick assembly mounted to the slide member wherein the joystick assembly includes a platform, a gripping post at a forward end of the platform and a pair of offset support posts at a rearward end of the platform. The gripping post is arranged to be grasped by the driver to move the joystick in the fore and aft direction when the driver's e forearm is resting on the platform. The pair of offset support posts flank the opposite sides of the forearm and provide a reaction surface for tilting the platform to activate the turn signal switches. The support post also held support and retain the driver's arm during operation of the joystick assembly to reduce the risk of inadvertent disengagement of the driver's hand from the joystick assembly.

The gripping platform is mounted to permit side-to-side tilting concurrently with fore and aft movement of the joystick assembly and slide member. The gripping platform includes means for preventing tilting of the platform in the fore-aft direction. In one embodiment, this means is in the form of fore and aft walls that engage a slide block on which the joystick is mounted. The walls are configured to permit side-to-side tilting.

A further feature of the inventive system contemplates that the slide member defines at least one wiring channel for receiving a plurality of electrical wires therethrough. The wires can be associated with the turn signal switches activated by tilting the joystick assembly. The wiring channels direct the wires from the switches through the slide member so that the plurality of wires can pass through the slide channel in the body of the hand controller without interfering with the sliding movement of the slide member within the slide channel.

In another embodiment of the invention, the manually manipulated hand controller includes a body defining a channel and an upward facing slot in communication with the channel. The slide member is disposed within the channel for sliding movement in a fore-aft direction. Means responsive to the position of the slide member within the channel can be provided for generating control signals indicative of

the desired vehicle command – i.e., acceleration or braking. The joystick assembly mounted to the slide member through the channel and is manually manipulable to slide the slide member in the fore-aft direction within the channel. Preferably, a slide block connects the joystick assembly to the slide member, with the slide block traversing the upward facing slot.

In a feature of this embodiment, the slide block has a length that is less than the length of the slide member in the fore-aft direction. A top plate is disposed over the upward facing slot, with the top plate defining a housing slot in communication with the upward facing slot and a recess surrounding the housing slot. A larger slot cover is disposed within the recess and has a length that is less than a length of the recess. The larger slot cover also defines a first slot in communication with the housing slot, wherein the first slot has a length greater than the length of the slide block but less than the length of the housing slot. The assembly is completed by a smaller slot cover also disposed within the recess between the larger slot cover and the slide block. The smaller slot cover has a length less than the length of the larger slot cover but greater than the length of the first slot. The smaller slot cover further defines a second slot having a length slightly greater than the length of the slide block and greater than the length of the first slot, but less than the length of the larger slot cover. This combination of recess and slot covers provides a closure for the housing slot so that the slide member can slide within the body with minimal risk of introduction of dust and other contaminants into the slide channel that might foul the movement of the slide member or disturb the associated electrical components.

It is one object of the invention to provide a system that can be easily managed by a person having a physical disability that might otherwise prevent that person from operating a motor vehicle. One important object is to provide such a system that can provide that driver with the greatest ability to control the vehicle braking and acceleration.

A further object of the invention resides in features that make the system easy to retrofit to an existing vehicle, specifically with as little disruption to the driver-side area

of the vehicle. Yet another object is accomplished by features that ensure stable and reliable actuation of the brake pedal, especially in an emergency braking condition.

These and other objects, as well as many benefits of the present invention, will become apparent upon consideration of the following written description, taken together with the accompanying figures.

DESCRIPTION OF THE FIGURES

FIG. 1 is a perspective view of one type of prior art vehicle control system.

FIG. 2 is front perspective view of a vehicle dashboard and vehicle control systems with the joystick control system in accordance with one embodiment of the present invention.

FIG. 3 is a perspective view of the joystick controller component of the joystick control system shown in **FIG. 2**.

FIG. 4 is a top view of the control block of the joystick controller shown in **FIG. 3**.

FIG. 5 is an end partial cross-sectional view of the control box shown in **FIG. 4**, taken along line **5-5** as viewed in the direction of the arrows.

FIG. 6 is an enlarged perspective view of a spring stop used with the control box shown in **FIGS. 4** and **5**.

FIG. 7 is an end partial assembly view of components of the joystick controller shown in **FIG. 3**.

FIG. 8 is top elevational view of a slide block incorporated into the partial assembly shown in **FIG. 7**.

FIG. 9 is a side view of a further partial assembly of components of the joystick control system shown in **FIG. 3**.

FIG. 10 is an end view of the rocker and hand-held components of the joystick control system shown in **FIG. 3**.

FIG. 11 is an exploded view of a top portion of the control box of the joystick control system shown in **FIG. 3**.

FIG. 12 is a top view of an actuator control apparatus used with the vehicle control system shown in **FIG. 2**.

FIG. 13 is an enlarged perspective view of the integration of the primary and secondary brake actuators to the brake pedal in accordance with the embodiment shown in **FIG. 2**.

FIG. 14 is an enlarged perspective view of the integration of the accelerator actuator integrated with the accelerator pedal in accordance with the control system embodiment shown in **FIG. 2**.

FIG. 15 is an enlarged perspective view of the mounting system for supporting the components of the vehicle controls system shown in **FIG. 2**.

FIG. 16 is a bottom perspective view of a controller housing, rack gear, sensor and limit switches in accordance with one embodiment of the joystick controller of the present invention.

FIG. 17 is a top view of the rack gear and a limit switch depicted in **FIG. 16**.

FIG. 18 is a partial cross-section view of the interface between the rack gear and drive link shown in **FIG. 12**.

FIG. 19 is a representation of the mounting plate for the assembly shown in **FIG. 12** with an alternative hinge arrangement in accordance with another embodiment of the invention.

DESCRIPTION OF THE PREFFERED EMBODIMENTS

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and described in the following written specification. It is understood that no limitation to the scope of the invention is thereby intended. It is further understood that the present invention includes any alterations and modifications to the illustrated embodiments and includes further applications of the principles of the invention as would normally occur to one skilled in the art to which this invention pertains.

The present invention contemplates a vehicles control system for integration into an existing vehicle. In particular, the vehicle control system **20** of the present invention interfaces with the vehicle brake pedal **B** and accelerator pedal A, as shown in **FIG. 2**. Moreover, the control system **20** is supported relative to the column for the steering wheel **S**, and requires only minimal modification to the vehicle dashboard **D**. As is typical in the industry, the vehicle is preferably a van-type vehicle, such as the van **V** depicted in **FIG. 1**, since vehicles of this type more readily accommodate wheelchair-bound drivers. However, it is understood that the principles of the present invention can be implemented on vehicles of virtually any type, including sedans, with appropriate modification and adjustment of the relative dimensions of the system **20**.

In the illustrated embodiment, the control system **20** is configured for controlling only the brake and accelerator pedals - i.e., the system does not provide an interface to control the steering of the vehicle. However, it is understood that the principles of the present invention can be integrated into a system that permits vehicle steering control other than through the steering wheel **S** itself. For instance, as disclosed in the aforementioned '416 Patent, steering control can be implemented by providing 2-axis movement of the joystick controller. However, for the purposes of the present invention, the control system **20** is disclosed as operating only the brake and accelerator pedals.

As shown in **FIG. 2**, the control system **20** includes a joystick controller supported by a control box **24**. In one aspect of the invention the control box **24** is supported by an arm **26** that is mounted to the steering column by way of a steering column mount **28**. The steering column mount also supports an actuator mechanism **30**

from which extends actuators for controlling the movement of the brake pedal **B** and the accelerator pedal **A**. In the preferred embodiment, the actuator mechanism **30** includes a primary brake actuator **32** and a secondary brake actuator **34** that integrates with the brake pedal. In addition, the actuator mechanism **30** includes an accelerator actuator **36** that connects to the vehicle accelerator pedal.

Details of the joystick **22** and control box **24** can be discerned from **FIGS. 3-10**. As shown in **FIG. 3**, the joystick controller **22** includes a grip platform **40** from which projects a number of posts. In a preferred configuration, the platform **40** supports a gripping post **41** and offset support posts **42**. This configuration is usable by most physically-impaired drivers by simply gripping the post **41** with the forearm positioned between the offset support posts **42**. This particular configuration has been found to be very comfortable to the driver and amenable to the precise, controlled movements necessary to manipulate the joystick controller **22**. It should be understood that other hand interfaces may be implemented in lieu of the posts **41, 42**. For instance, a dual or single post arrangement can be used, as well as a ball grip or a palm grip, all as known in the art.

The grip platform **40** is mounted to a rocker **44** that only permits side-to-side rocking movement. This rocking movement allows the driver to depress turn signal switches **48** mounted to opposite sides of a slide block **46**. Thus, by rocking or wobbling the platform **40** to the left or to the right the driver can operate the vehicle turn signals.

The slide block **46** is mounted for linear sliding movement relative to the control box **24**. Thus, the physically-impaired driver can move the grip platform **40** forward or backward to operate either the accelerator or the brake, respectively.

The control box **24** includes a cover that houses the internal components of the control box. For instance, controller circuitry **52** can be mounted within the cover **50**, where the circuitry translates movement of the joystick controller **22** to specific control signals fed to the actuator mechanism **30** as described herein. The control box **24** further includes a controller housing **54** to which the cover **50** is mounted. Preferably, the controller housing **54** is in the form of a substantially rectangular block as can be discerned from **FIGS. 4** and **5**. The cover **50** is preferably formed from a stamped sheet

of material where the side and end walls are initially provided flat, and then folded upward and welded together to form a box about the controller housing **54**. The housing preferably includes a top plate **56** that defines a flange **66** against which the cover **50** abuts to form a sealed enclosure within the cover **50** and controller housing **54**.

In one feature of the invention, the controller housing **54** supports a controller slide member **58** that is disposed within a slide channel **60**. Preferably, the controller slide member **58** is generally cylindrical in configuration and has a diameter that is slightly less than a cylindrical diameter of the slide channel **60** (see **FIG. 5**). As shown in **FIGS. 7** and **9**, the controller slide member **58** is connected to the slide block **46** so that linear movement of the slide block **46** by way of manual pressure on the grip platform **40** will cause the controller slide member **58** to move forward or backward within the control housing **54**. A housing slot **62** and recess **64** are provided in the top plate **56** so that the controller slide member **58** can be connected to the slide block **46** (see **FIG. 5**).

In accordance with a further aspect of the invention, the controller slide member **58** is provided with a tactile feedback and centering feature. In the preferred embodiment, this feature is provided by opposing springs that center the controller slide member **58** within the slide channel **60** when no pressure is applied to the grip platform **40**. In addition, the opposing springs provide tactile feedback or resistance as the controller grip platform **40**, and therefore the controller slide member **58**, is moved further in the forward or backward directions.

Thus, in accordance with the illustrated embodiment, the controller housing **54** is provided with a pair of opposite spring channels **68**, **69** that flank opposite sides of the slide channel **60**, as best seen in **FIG. 5**. The channels preferably extend through the entire length of the controller housing **54** to facilitate assembly of the components of the control box. Corresponding spring stops **70, 71** can be disposed within opposite ends of the spring channels **68, 69**, as depicted in **FIG. 4**. The spring stops can be friction-fit pins such as the pins **70, 71** shown in **FIG. 6**. In this instance, the pins are pressed into the appropriate ends of the spring channels **68, 69** to contain corresponding springs **73,74** within the spring channels. Once the springs **73, 74** have been loaded into the corresponding spring channels **68, 69**, travel stops **76, 77** can be inserted into the

controller housing **54** to block the open ends of the two channels. In a preferred embodiment, the travel stops **76** can be in the form of screws threaded into bores defined in the controller housing **54** that intersect the open ends of the spring channels **68, 69**.

As can be appreciated from **FIG. 4**, the two springs **73, 74** are arranged to act in opposite directions. The controller slide member **58** is provided with spring engagement pins **79, 80** at its corresponding opposite ends. In the illustrated embodiment, the pins **79, 80** are press-fit into corresponding bores formed in the opposite ends of the slide member **58**. These engagement pins **79, 80** are arranged to contact the free end of the springs **73, 74** as shown in **FIG. 4**. Thus, it can be appreciated that each spring **73, 74** is trapped or contained between a corresponding spring stop **70, 71** and an engagement pin **79, 80**. With this arrangement, it should be understood that movement of the controller slide member **58** in one direction, for instance the forward direction, will compress one spring, such as spring **73**, while permitting the opposite spring, such as spring **74**, to extend. Likewise, movement of the controller slide member **58** in the opposite, or backwards, direction will compress the spring **74** and extend the spring **73**.

Preferably, the two springs are configured so that they maintain some pressure against the engagement pins **79, 80**, even when the pins reach their corresponding travel stops **76, 77**. In other words, each of the springs **73, 74** preferably have a free length that is greater than the distance between the end of the corresponding spring stops **70, 72** and the corresponding travel stops **76, 77**. In one aspect of the invention, the spring constants of the two springs **73, 74** can be adjusted to provide a different tactile feedback depending on the direction of movement of the grip platform **40**. For instance, the spring **73** can be stiffer than the spring **74** so that forward movement (as designated by the arrow F in **FIG. 4**) counters greater resistance than movement in the opposite direction. If the forward movement of the controller slide member **58** corresponds to actuation of the accelerator pedal A, then the increased tactile resistance will allow for more controlled acceleration of the vehicle. On the other hand, having a less stiff spring **74** countering movement in the opposite or backward direction minimizes the resistance to movement of the joystick controller **22** when braking is desired. This can be especially important where a hard or emergency braking is necessary, in which case the tactile feedback

feature of the system **20** should not pose an impairment to a quick response in case of an emergency.

In an alternative embodiment, the spring stops **70**, **71** can be threaded, and the corresponding ends of the spring channels **68**, **69** also threaded to permit threaded adjustment of the spring stops. In this manner, the spring stops **70**, **71** can be threaded deeper into the corresponding spring channels **68**, **69**, to increase the resistive force generated by the corresponding springs **73**, **74**. The provision of threaded spring stops **70**, **71** allows for more precise adjustment of the spring force resistance to forward or backward movement of the controller slide member **58**, so that the joystick controller and control box **24** can be tailored to a particular driver's preference.

As shown in **FIG. 7** the slide block **46** supports the turn signal switches **48**. In a preferred embodiment, the slide block **46** defines switch bores **98** into which each turn signal switch **48** is disposed. Preferably the switches are push-button type switches that are activated by pressure on the spindle of the switch. The switches can be on-off type, meaning that the switches must be depressed to turn the signal on and off. Alternatively, the switches can require continued pressure and are deactivated when the switch is released.

As also indicated above, the slide block **46** supports the rocker **44**. As can be seen in **FIGS. 7**, **9**, and **10**, the rocker **44** includes sidewalls **82** that flank the sides of the slide block **46** exposed above the control box **24**. The side walls **82** are provided only on two sides of the rocker **44** so that the rocker **44** can be rocked or pivoted only along a plane parallel to the side wall **82**, as indicated by the double arrows **R** shown in **FIG. 7**. These side walls **82** provide means for preventing the rocker and platform **40** from tilting in the fore-aft direction of movement of the joystick assembly **22.**

The rocker **44** also defines a body **83** that is integral with the side walls **82**. The body defines a bolt recess **92** that allows the rocker **44** to be bolted to the slide block **46**. In a preferred embodiment, the rocker and slide block are also bolted to the controller slide member **58**, as shown in **FIG. 9**, to form a fully integrated construction. Thus, the controller slide member **58** can be provided with a T-nut bore **84** (**FIGS. 4** and **9**). A T-nut **85** can extend upward into the bore **84** to integrate with a bolt **87** that is fed through

the bolt recess **92** of the rocker **44** and through a corresponding bore **88** (see **FIG.8**) defined in the slide block **46**. The bolt then engages the T-nut **85** internally within the bore **84** or the bore **88**, depending on the length of the T-nut **85**.

Since the rocker **44** must be permitted to rock from side to side as depicted by the direction arrow R in **FIG. 7**, the rocker cannot be solidly fixed to the slide block **46**. Thus, a rocker support **90** can be provided that offsets the rocker **44** from the slide block **46**, as shown in **FIGS. 7** and **9**. Preferably, the rocker support **90** is in the form of a flexible tubular body, such as a thick rubber washer. In addition, it is contemplated that the bolt recess **92** be sufficiently larger than the head of the rocker bolt **87** so that the rocker **44** has freedom of movement even when the bolt is engaged to the T-nut **85**. In a further aspect of the preferred embodiment, a curved washer (not shown) can be disposed between the base of the bolt recess **92** and the head of the rocker bolt **87** so that the rocker is free to pivot even while the bolt remains fixed in position.

The control system **20**, and particularly the control box **24** of the present invention, contemplates unique features associated with the slide block **46**. In particular, the slide block **46** includes a body **94** from which extends a slide extension **96**. The slide extension is configured to fit through the housing slot **62** (**FIG. 4**) in the controller housing **54** of the control box **24**. Thus, the slide extension **96** has a width that is less than the width of the housing slot **62**. It is of course understood that the housing block **62** intersects the slide channel **60** so that the slide extension **96** can mate with the controller slide member **58**. Moreover, it is understood that the length of the slide extension **96** (i.e. its dimension along the long axis of the housing slot **62**) is significantly less than the length of the slot **62** itself, in order to permit the expected degree of movement of the controller slide member **58** within the control box **24**. Thus, as shown seen in **FIG. 9**, the length of the slide extension **96** is less than the length of the controller slide member **58**. Preferably, the controller slide member **58** defines a recess to interlock with the free end of the slide extension **96** when the entire assembly is bolted together by way of the T-nut **85** and rocker bolt **87** as described above.

As shown in **FIG. 8**, the slide block body **94** defines switch bores **98** at the lateral sides of the body. The switch bores **98** support the turn signal switches **48**, which

necessarily include associated wiring. In order to accommodate the wiring and to prevent the wiring from interfering with the sliding movement of the controller slide member **58**, the slide block body **94** is provided with a unique arrangement of wiring bores. In particular, the body **94** defines a pair of angled wiring bores **102** associated with each of the switch bores **98**. The angled bores **102** intersect the corresponding switch bores **98** near the open end of the bores but inboard of the block body **94**. In this way a wire, such as a wire **W** shown at the right side of the slide block **46** in **FIG. 7** can accept the turn signal switch **48** and pass upward through an angled wiring bore **102** without being exposed outside the slide block body **94**. The wires are threaded upward through the angled bores **102** and can pass along wiring channels **104** (**FIG. 8**) defined in the upper surface of the slide block body **94**. The wires can then be threaded downward through a pair of feed bores **106** situated at the fore and aft sides of the slide block body **94**. These feed bores **106** communicate with corresponding feed bores **107** defined in the controller slide member **58** as shown in **FIG. 9**. Thus, the wires **W** can be fully contained within the slide block body free and clear of the controller slide member **58** as shown in **FIGS 7** and **9**. These wires can then be fed to the controller circuitry **52** mounted within the cover **50** (see **FIGS. 5** and **9**).

As depicted in **FIG. 3**, the control box **24** includes a top cover **110** that fits over the top plate **56** of the controller housing **54**. Details of the top cover are shown **in FIG. 11**. A first feature is integrated into the top plate **56** of the controller housing **54**. As indicated above, a slot **62** is defined in top plate **56** for sliding movement of the slide block **46**. The top plate **56** also defines a recess **64** surrounding the slot **62**. The opposite ends of the recess form tapered ends **65** that taper inwardly toward the longitudinal axis. In addition, the tapered ends **65** slope gradually upward toward the opening of the housing recess **64**. The purpose for the tapered portions **65** will be explained in more detail below.

The top cover **110** is configured to sit generally coextensively with the top plate **56**. The top cover **110** defines a slot **112** that has a length and width substantially equal to the length and width of the slot **62**. It is of course understood that the slide block **46** also extends through the slot **112** and reciprocates within that slot as well as within the slot **62**. Sandwiched between the top cover **110** and the top plate **56** are a pair of slot

covers **114** and **118**. The smaller slot cover **114** defines a slot **115** that has a length and width slightly larger than the length of the slide block **46**. The larger slot cover **118** also defines a slot **119** that is larger in dimension than the slot **115** in the smaller slot cover **114**, but is smaller than the slots **62** and **112**.

The two slot covers **114** and **118** cooperate with each other to, in effect, provide a seal between the inside of the control box **24** and the environment outside the box. Thus, the two slot covers **114**, **118** are free to slide back and forth within the housing recess **64** and are free to slide relative to each other. The largest slot cover **118** substantially covers the housing slot **62** in the controller housing **54**. The smaller slot cover **114** covers a substantial portion of the slot **119** in the larger slot cover **118**. Thus, the two slot covers **114**, **118** provided overlapping coverage to minimize the chance of dust and dirt passing through the slot **62** and infecting the inner workings of the control box **24**.

The tapered ends **65** of the housing recess **64** act as a sort of particle ejector. In other words, when dirt and dust does manage to pass through the top cover **110** and into the recess **64**, movement of the larger slot cover **118** along the tapered ends **65** of the recess **64** has a tendency to push or eject dirt and dust particles from the recess. In this way, the combination of the slot covers **114**, **118** with the tapered **65** help achieve a self-cleaning action for the control box **24**.

Referring back to **FIG. 9**, it can be seen that in one embodiment of the invention a rack gear **125** is mounted to the underside of the controller slide member **58**. The rack gear **125** moves forward and backward with the controller slide member **58** which movement is controlled by the vehicle driver by way of the joystick controller **22** and grip platform **40**. The rack gear **125** interfaces with the control circuitry **52** to produce a signal indicative of the direction and magnitude of movement of the controller slide member **58**, or ultimately the joystick controller **22**.

In one embodiment, the rack **125** includes teeth **126** that mesh with a sensor gear **128** of a movement sensor **127** that is supported by the controller circuitry **52**, as shown in **FIG. 9**. The teeth **126** and the interface with the sensor gear **12°** in this embodiment are vertical, or aligned with the slot **60** in the controller housing **54**. In an alternative embodiment, shown in **FIG. 16**, a rack gear **200** is connected to the underside of the

controller slide member **58** by a pair of fasteners **204**. The rack gear **200** includes laterally oriented teeth **202** that mesh with a gear **242** of a movement sensor **240** that is supported on the underside of the controller housing **54**. The interface between the rack gear **200** and the sensor gear **242** is essentially lateral relative to the controller housing **54**.

With either embodiment, i.e., the rack gear **125** or **200**, the direction and angular magnitude of rotation of the sensor gear **128** is translated by appropriate circuitry within the controller circuitry **52** into control signals. The control signals pass through control signal wires **130** to the actuator mechanism **30** to control the actuators as described wherein. It is understood that other forms of position and/or movement detectors or transducers may be used to translate the longitudinal movement of the grip platform **41** to signals indicative of a braking or an acceleration command from the vehicle operator.

More particularly, the controller circuitry **52** can include electronics and/or software that translate the clockwise or counter-clockwise rotation of the sensor gear **128** into an acceleration or a braking signal. In a specific embodiment, clockwise rotation of the sensor gear **128** corresponding to forward movement of the controller slide member **58** corresponds to an operator acceleration command. Conversely, counter-clockwise rotation of the sensor gear **128** can correspond to a braking command. Movement of the controller slide member **58** to either its forward or backward limits will cause the sensor gear **128** to move to it fullest clock wise or counter-clockwise angular extent. The circuitry and/or software within the control circuitry **52** can translate that movement into an appropriate command to fully depress the accelerator pedal **A** or the brake pedal **B.** With respect to the full stroke backward movements of the controller slide member **58** (and of course the joystick controller **22**), can be calibrated to define an emergency braking condition.

Thus, the controller circuitry **52** generates the control signals along the signal wires **130** that are fed to the actuator mechanism **30**. In a preferred embodiment, the control wires **130** can pass through the hollow interior of the support arm **26**. The control wires provide the acceleration/braking control signals to motor control circuitry **135** disposed within the actuator mechanism **30**. As depicted in **FIG. 2**, the actuator

mechanism **30** includes an actuator housing **192** that is configured to contain the motor control circuitry **135**, as well as the motor assemblies depicted in **FIG. 12**. Preferably, the portion of the actuator housing **192** facing the driver includes padding **194** to prevent injury if it is accidentally contacted by the vehicle operator.

Turning to **FIGS. 12** the details of the actuator mechanism **30** can be seen. In the preferred embodiment, the brake pedal **B** and accelerator pedal **A** are controlled by way of electric motors. Thus, the motor control circuitry **135**, which is preferably a microprocessor, transmits various control signals through motor control wires **137** fed to the actuator system **138**. In the preferred embodiment, the brake pedal **B** is controlled by a primary brake assembly **140** and a secondary brake assembly **150**. The two assemblies provide a fail-safe redundancy in the event of failure of one of the two brake assemblies. Each assembly **140, 150** includes a corresponding brake or motor **141, 151**, drive spindle **142, 152** and rack gear **143, 153**. Each rack gear is connected to a drive link **144, 154**, each of which terminates in a drive tab **145, 155**. Preferably, each drive tab **145, 155** is in the form of an eyebolt, as depicted in **FIG. 18**.

In addition, as shown in **FIG. 18**, each rack gear, such as the illustrated rack gear **143**, is telescopically situated within a cavity **144a** of the drive link **144**. With this configuration as the rack gear **143** moves right, corresponding to an actuation of the primary brake motor **141**, the rack gear slides within the cavity until the end **143a** of the rack gear contacts the base of the cavity **144a**. At this point, the rack gear pushes the drive link **144** to ultimately depress the brake pedal **B**. On the other hand, when the rack gear **143** is retracted toward the left in **FIG. 18**, the link slides freely within the cavity **144a** and does not exert any restorative force on the drive link **144** or the brake pedal. Nominally, the brake pedal is self-restorative, meaning that it will naturally return to its neutral position. Optionally, a separate spring may be attached at one end to the brake pedal and at an opposite end to the actuator system **138** to assist restoring the brake pedal to its neutral non-braking position after the rack gear **143** has been retracted. One primary benefit of the telescoping interface between the rack gear **143** and the drive link **144** is that a different vehicle operator will be able to depress the brake pedal by normal foot operation. When the brake pedal **B** is depressed, the drive link **144** is drawn downward, while the rack gear **143** remains relatively stationary.

The drive link **144, 154** interface with the brake pedal **B** through the brake pedal arm **BR** as shown in **FIG. 14**. More specifically, a linking bracket **175** is fixed to the brake pedal arm **BR**. Attachment bolts **176** mate with the drive tabs **145, 155** to fix the drive links **144, 154** to the linking bracket **175**. Preferably, the drive pins **145, 155** permit some degree of pivoting of the drive links **144, 154** relative to the linking bracket **175.** However, the drive link **144, 154** must be solidly connected to the linking bracket **175** along the longitudinal axis of the links so that translation of the links directly and instantly cause a corresponding downward movement of the brake pedal **B** by operation of the force on the brake pedal arm **BR**. It should be readily apparent that immediate and accurate movement of the brake pedal **B** is essential to the safety of the vehicle driver. Thus, the redundant primary and secondary brake assemblies **140, 150** help ensure that the failure of any single brake assembly will not compromise the braking function of the vehicle.

In addition, the present invention contemplates a unique manner for supporting the actuator mechanism **30** to insure that the driving force generated by the primary and secondary brake assemblies is always perpendicular to the brake pedal arm **BR**, even as the arm **BR** is itself pivoted as the brake pedal **B** is depressed. This beneficial feature is accomplished through the mount **28** that is utilized to mount both the support arm **26** and the actuator mechanism **30**. More specifically, the mount **28** is adapted to engage the vehicle steering column underneath the dashboard **D** as shown in **FIG.2**. Referring to **FIG. 15**, the details of the steering column mount **28** can be seen. In particular, the mount **28** includes a support arm mount **182** that is preferably in the form of a hollow cylinder. A number of bolts **183** can pass through the cylindrical mount **182** and engage corresponding bolt holes (not shown) in the support arm **26** disposed within the mount **182**.

The steering column mount **28** is preferably formed as a pair of clamp halves **185, 186**. The two halves are configured to define a steering column opening **187** when the halves are bolted together. With this steering column mount **28** configured as shown in **FIG. 15**, only minor modification is required to the vehicle dashboard **D**, as shown in **FIG. 2**. In particular, the side of the dashboard directly beneath the steering column can be cut out to provide access to fix the clamp halves **185**, **186** about the steering column.

In prior remote braking systems, the brake actuator includes a roller that contacts the brake pedal so the roller translates along the width of the pedal as it is depressed. With this prior approach, the line of action of the actuator force changes, thereby decreasing the mechanical advantage for the actuator. Moreover, the roller is susceptible to slipping off the brake pedal if the roller travels too much. The present invention eliminates these problems by providing the steering column mount **28** with a hinge **190** that is fixed to the underside of the mount, and preferably to the underside of the clamp half **185**. The hinge plate **190** can include a number of screw holes **191** that allow the hinge plate to be fastened to the actuator housing **192** (**FIG. 2**). The hinge plate **190** thus permits pivoting of the actuator housing **192** relative to the fixed steering column mount **28**. As the drive links **144, 154** are extended to depress the brake pedal **B**, the angular position of the actuator housing **192** is adjusted to account for the pivoting movement of the brake pedal arm **BR**, thereby maintaining a perpendicular force on the brake pedal arm **BR** by the extension of the primary and secondary brake assembly drive links.

In an alternative embodiment, the hinge plate **190** of **FIG. 15** is replaced by a spindle configuration, as shown in **FIG. 19.** In this embodiment, a spindle **198** is rotatably supported within two collars **197** that are mounted to the mounting plate **196** of the actuator system **138**. The cylindrical mount **182** can be interleaved between the two collars **197** with the spindle **198** extending through the mount. The spindle **198** thus retains the pivoting feature of the embodiment shown in **FIG. 15**.

Returning to **FIG. 12**, the actuator system **138** also includes an accelerator actuator assembly **160**. The actuator assembly includes a drive motor **161** that rotates a drive spindle **163**, preferably through a transmission, such as planetary gearing, to step down the motor speed to an appropriate speed for the rest of the accelerator actuator system **138**. Preferably, the actuator assembly includes a clutch **162** between the motor/transmission and the spindle. In a preferred embodiment, the clutch is an electromagnetic clutch that is activated by a signal from the control circuitry **135** through one of the control wires **137**. The clutch **162** can be a free-wheeling clutch when no electrical current is provided to the clutch. When power is applied to the drive motor **161** and clutch **162**, the clutch engages so that rotation of the motor leads to direct rotation of the drive spindle **163**.

As with the primary and secondary brake assemblies, the accelerator assembly includes a rack gear **164** that is a meshed engagement with the drive spindle **163**. The rack gear **164** terminates in a U-joint **166** that mounts to the drive link **168**. Thus, the U-joint **166** permits multiple degrees of freedom of movement to account for actuation of the accelerator assembly. In addition, this U-joint allows the accelerator pedal actuator to accommodate the pivoting of the actuator housing **192** that occurs when the brake pedal is depressed, as described above. With this configuration, the independence between the brake actuators and the accelerator actuator can be maintained while the overall size of the actuator system **138** can be kept to a minimum.

Preferably, the link **168** includes a link adjustment feature **169** that permits fine adjustment of the length of the accelerator drive link **168** upon installation, namely by adjusting the relative position of the link halves **168a, 168b**. The drive end of the link **168** forms a clevis **170** that can engage the accelerator pedal **A** linkage by way of a link bracket at **178** and bolt **179**, as shown in **FIG. 14**. The clevis end **170** of the link accommodates pivoting of the link relative to the link bracket **178** as the drive link **168** is extended to depress the accelerator pedal **A**. Where the drive links **144, 154** for the brake actuators are configured as shown in **FIG. 18**, the drive link **168** of the accelerator actuator can be similarly configured to allow telescoping movement between the U-joint **166** and the clevis end **170**, or more specifically between the link halves **168a, 168b**.

In the preferred embodiment, the free-wheeling clutch **162** essentially disconnects the drive link **168** from the motor **161** when power is shut off to the motor and clutch. In other words, when the joystick controller **22** (and ultimately the controller slide member **58**) are not moved forward, but are instead at the neutral position as depicted in **FIG. 4**, or moved backward in a braking operation, then the accelerator drive link **168** is free to translate back and forth. With this arrangement, the return spring of the accelerator pedal is all that is necessary to push the drive link **168** back toward the actuator mechanism **30**, restoring the rack gear **164** to its neutral position.

On the other hand, the primary and secondary brake assemblies do not permit a free-wheeling movement. In other words, the brake motors **141, 151** do not incorporate a clutch between the motor and the drive spindle **142**. When power is terminated to either

of the motors, the motors are held in whatever position they hold at the time power is terminated, which means that the rack gear **143**, **153** are also held in their particular position. Ultimately, if the drive motors are fixed in position, then the drive links **144**. **154** are fixed in position, which means that if the brake pedal **B** was depressed when the power to the brake assembly motors is terminated, then the brake will be maintained depressed. This is an important failsafe feature that permits release of the brake should electrical power to the actuator system **138** be interrupted for any reason.

The brakes are released, and more particularly, the primary and secondary brake motors **141**, **151** are reversed, when the joystick controller **22** is moved to its neutral position, or forward of the neutral position. When the joystick is returned to its neutral position after a braking maneuver has been completed, this return movement is sensed by the control circuitry **52** which sends a signal to the motor control circuitry **135** to reverse the direction of the brake motors **141, 151**. The motors are then reversed and the drive racks **143, 153** are retracted to release the brake pedal **B**. In one embodiment of the invention, proximity sensors or limit switches can be used to sense when the drive racks are at the limits of their stroke. In other words, when the brake motors **141, 151** are driven in reverse, a limit switch can be tripped by movement of the drive racks **143, 153** to prompt the motor control circuitry **135** to issue a motor stop command. Likewise, limit switches positioned at the limit of forward movement of the drive racks, corresponding to completely depressing the brake pedal **B**, can send a signal to the motor control circuitry to issue a motor stop command.

In addition to or in lieu of limit switches, the barking and steering rack gears can be monitored by position encoders. In one embodiment, a position encoder **159** can mesh with the rack gear **143** for the primary brake assembly **140**. Likewise, a position encoder **172** can mesh with the rack gear **164** for the accelerator assembly **160**. The position encoders can provide signals to the microprocessor **135** indicative of the stroke of the corresponding rack gear. When the rack gear reaches the limit of its extension or retraction travel, the microprocessor can issue an appropriate stop or return command to the corresponding motor **151** or **161**.

In a more preferred embodiment of the invention, a limit switch can be used to sense a return of the brake motors to the neutral (non-braking) position, but an open-loop control system is used to determine when to stop the brake motors during a braking maneuver. In prior systems, a closed loop control system provides a positive limit to movement of the braking controls. These closed loop systems cannot account for mechanical variations in the operation of the vehicle brakes. For instance, over time, the brake pads wear, which means that the brake pedal **B** must be depressed farther. A closed loop system cannot account for this variation. On the other hand, the open loop control of the present invention accounts for this variation by, in essence, sensing the increase in resistance that occurs when the brake pedal is at or near its fully depressed position.

Thus, in one embodiment of the invention, the motor control circuitry **135** uses feedback on the current delivered to the motors **141, 151** to determine when to stop the motors at the end of a braking stroke. When the brake assembly **140** is actuated to depress the brake pedal **B** near its mechanical limit, the braking system exerts greater resistance to continued movement of the pedal, and consequently of the drive links **144, 154** of the brake assembly. As the motor torque increases to meet this increased load, the motor current increases. The motor control circuitry can sense this increase in current, either as a function of time or magnitude, to determine that the brake pedal is fully depressed. The motor control circuitry **135** then issues a motor stop command because the brake pedal has reached the mechanical limit of its stroke.

In another aspect of the motor control circuitry **135**, the motor current is constantly monitored to determine if a problem exists in the braking or acceleration motors. If the current delivered to any motor is too low, an open circuit may exist. If the current delivered to the motor is too high, a short may exist in the motor. In either case, the function of the actuator mechanism **30** is compromised. The motor control circuitry **135**, or microprocessor, can transmit a warning signal or illuminate an enunciator light to call attention to the condition.

In one feature of the invention, the drive components of the actuator system **138** are mounted on a common support plate **196** that forms part of the actuator housing **192**.

Thus, the primary and secondary brake motors **141, 151** and the accelerator motor **161** are mounted on this support plate. Moreover, the rack gears **143, 153** and **164** are slidably supported on the plate **196**. This common support characteristic reduces the size of the envelop occupied by the actuator system **138** and minimizes the incursion into the driver's space behind the steering wheel **S**.

In specific embodiments of the invention, the motors in the actuator system **138** are precision DC motors. The accelerator motor **161** can be a 90 watt, 15V motor, with a no load speed of 7070 rpm and a maximum continuous torque of 77.7 mNm. Preferably, the accelerator motor is geared down at a ratio of 74:1 to rotate the drive spindle **163**. In the specific embodiments, the primary brake motor **141** can be a 150 watt, 12V motor with a no load speed of 6920 rpm and a maximum continuous torque of 98.7 mNm. The primary brake motor can be geared down at a ratio of 156:1 to rotate the spindle **142**. The secondary brake motor **151** can be similar to the primary motor.

In an alternative embodiment, the secondary brake motor can be a 150watt, 48V motor with a no load speed of 7850 rpm and a maximum torque of 201 mNm. This alternative motor is geared down at a ratio of 43:1. In this embodiment, the secondary brake motor **151** operates as an emergency braking motor that is activated when the joystick is "pegged". In other words, in an emergency braking condition, the joystick is pulled back as far and as quickly as possible. The control circuitry **52** can be configured to sense this rapid movement and issue an appropriate signal to the motor control circuitry.

However, in a preferred embodiment, a limit switch is positioned relative to the rack gear **125** so that when the rack gear is moved to its farthest extent by the joystick, the limit switch is actuated. When this limit switch is actuated, a signal is sent to the motor control circuitry to activate the secondary brake motor **151**, which then quickly depresses the brake pedal for an emergency braking maneuver. In this alternative embodiment, the secondary brake motor is not normally activated, with the primary brake motor **141** absorbing the braking function of the system.

In one embodiment of the invention shown in **FIG. 16**, a pair of limit switches **220, 230** can be provided at the opposite ends of the stroke for the controller slide **58** and

the rack gear **200** carried by the slide. The rack gear is configured for specific interaction with the two limit switches to provide an emergency braking function and to disconnect the accelerator motor clutch **162** when no acceleration command has been issued. Specifically, referring to **FIG. 17** details of the rack gear **200** and one of the limit switches **220** can be seen. The limit switch **220** can include a spring biased pushbutton **224** that moves into and out of the switch housing **221** in the direction of the aligned arrows. The switch includes a spring arm **226** that bears against the pushbutton **224**. The free end of the spring arm **226** includes a follower element **228** that can be in the form of a roller or a rounded contour to the arm. The follower element engages the rack gear **200** and governs the movement of the spring arm, and ultimately whether the arm depresses the pushbutton.

As shown in **FIG. 17**, the rack gear **220** includes a neutral edge **206** corresponding to a no acceleration condition, or a braking condition. When the follower element **228** contacts the neutral edge, the arm **226** is in its neutral position in which it does not depress the pushbutton **224**. When the rack gear **200** moves to the right, which corresponds to an operator input braking command through the joystick **22**, the follower element continues along the neutral edge and the pushbutton remains in its non-activated position. On the other hand, when the rack gear **200** is moved to the left, indicative of an acceleration command form the vehicle operator, the follower element rides up the sloped edge **208** to an activation edge **210**. As the follower rides up the sloped edge **208**, the follower element pushes the spring arm **226** toward the switch body **221** so that the spring arm depresses the pushbutton **224**.

The switch **220** includes an electrical connector **222** that can mate with a wiring harness forming part of the control signal wires **130 (FIG. 12)**. When the switch **220** is deactivated (i.e., when the follower element is in contact with the neutral edge **206**), a null signal is supplied to the motor control circuitry or microprocessor **135** directing the microprocessor to de-energize the clutch **162** for the accelerator assembly **160**. Thus, the accelerator motor **161** is isolated from the vehicle accelerator pedal **A** and the pedal cannot be depressed. On the other hand, when the switch **220** is activated (i.e., when the follower element engages the activation edge **210**), the closed switch directs the

microprocessor to engage the clutch, thereby coupling the motor **161** to the accelerator pedal.

At the other end of the spectrum, a second limit switch **230** can be constructed like the switch **220** just described. This second switch includes a follower element **238** that contacts the rack gear **200** when the gear is at the farthest right extent of its stroke. This position of the rack gear **200** corresponds to an emergency braking command when the vehicle operator has pushed the grip platform **40** of the joystick fully forward. Referring again to **FIG. 17**, the rack gear **200** includes a forward sloped edge **212** that slopes rearward to the activation edge **210**. When the rack gear is moved fully forward, the forward sloped edge **212** contacts the follower element **238** to depress the pushbutton and thereby activate the limit switch **230**. In the preferred embodiment, this limit switch **230** is connected to controls for an emergency braking system. This emergency braking system is preferably independent of the motor control circuitry **135** and independent of the primary and secondary braking motors **141, 151**. In one specific embodiment, the emergency braking system can constitute a four-wheel electric braking system that applies controlled barking to all wheels when the limit switch **230** is activated. With this specific embodiment, the emergency braking system bypasses the brake pedal **B** in favor of direct actuation of the vehicle brakes.

In the preferred embodiment of the invention, the electrical system of the control system **10** is connected to the vehicle electrical system. Preferably, this electrical connection is accomplished from the motor control circuitry **135**, in the actuator mechanism **30** mounted to the steering column, to the vehicle fuse box. The electrical components within the control box **24** for the joystick **22** can be supplied with power from the motor control circuitry, rather than independently from the vehicle electrical system. In one embodiment, the actuator mechanism **30** can include a back-up power supply, such as a battery, mounted within the actuator housing **192**. This battery back-up can thus supply electricity to the control circuitry to permit activation of the brake assemblies **140, 150** even after a loss of vehicle power.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same should be considered as illustrative and not

restrictive in character. It is understood that only the preferred embodiments have been presented and that all changes, modifications and further applications that come within the spirit of the invention are desired to be protected.